HOW INFORMATIVE ARE SINGLE WELL TRACING EXPERIMENTS? AN ASSESSMENT USING BAYESIAN EVIDENTIAL LEARNING

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Budgets dedicated to hydrogeological and environmental investigations are generally limited. When lucky, several boreholes/wells/piezometers are available and can be used to design pumping and tracing experiments. Most often, a very limited number of them can be used for investigation. In this context, single-well experiments such as slug tests, push-pull tests or point-dilution tests have been shown to provide crucial information for hydrogeologists. However, the collected information is mostly local and generally uncertain. Are those tests reliable enough to make accurate hydrogeological predictions? In this contribution, we investigate if short term push-pull tests can be used to predict the long-term behavior of hydrogeological systems. We combine field experiments with a probabilistic modeling approach called Bayesian Evidential Learning (BEL) to gain knowledge on the information content of our data sets. BEL relies on a set of prior models of the subsurface representing our prior uncertainty (structure of the aquifer, hydraulic conductivity, spatial heterogeneity, hydraulic gradient, …). Those models are used to simulate both the field experiment and the prediction of interest. A global sensitivity analysis is carried out to ensure that both are sensitive to the same parameters. Then, a direct statistical relationship is derived between the data and the prediction, using dimension reduction techniques and machine learning. Once the relationship is known, it is possible to derive the posterior distribution of the prediction corresponding to the observed field data, and thus its uncertainty. We first demonstrate and validate with field data that BEL is able to accurately predict a cyclic heat injection experiment from a simple push-pull test. Then, we use this experiment to predict the long-term temperature trend in an aquifer subjected to cyclic thermal energy storage. This prediction is necessary for the estimation of the heat storage capacity of the aquifer and to assess the risk of degradation of the biological and chemical state of groundwater. Finally, we compare the ability of different experimental set-ups to make this prediction, allowing us to derive the most informative experiment. Bayesian Evidential Learning is a flexible framework allowing to quantify the uncertainty of hydrogeological predictions without a full explicit inversion or calibration procedure. Therefore, we think its range of applications will quickly rise in the future among scientists and practitioners.

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